# A FEW WORDS

ON

# PORTLAND CEMENT.

BY

## A MANUFACTURER.

D. L. COLLINS
(GIBBS & CO., LIMITED).

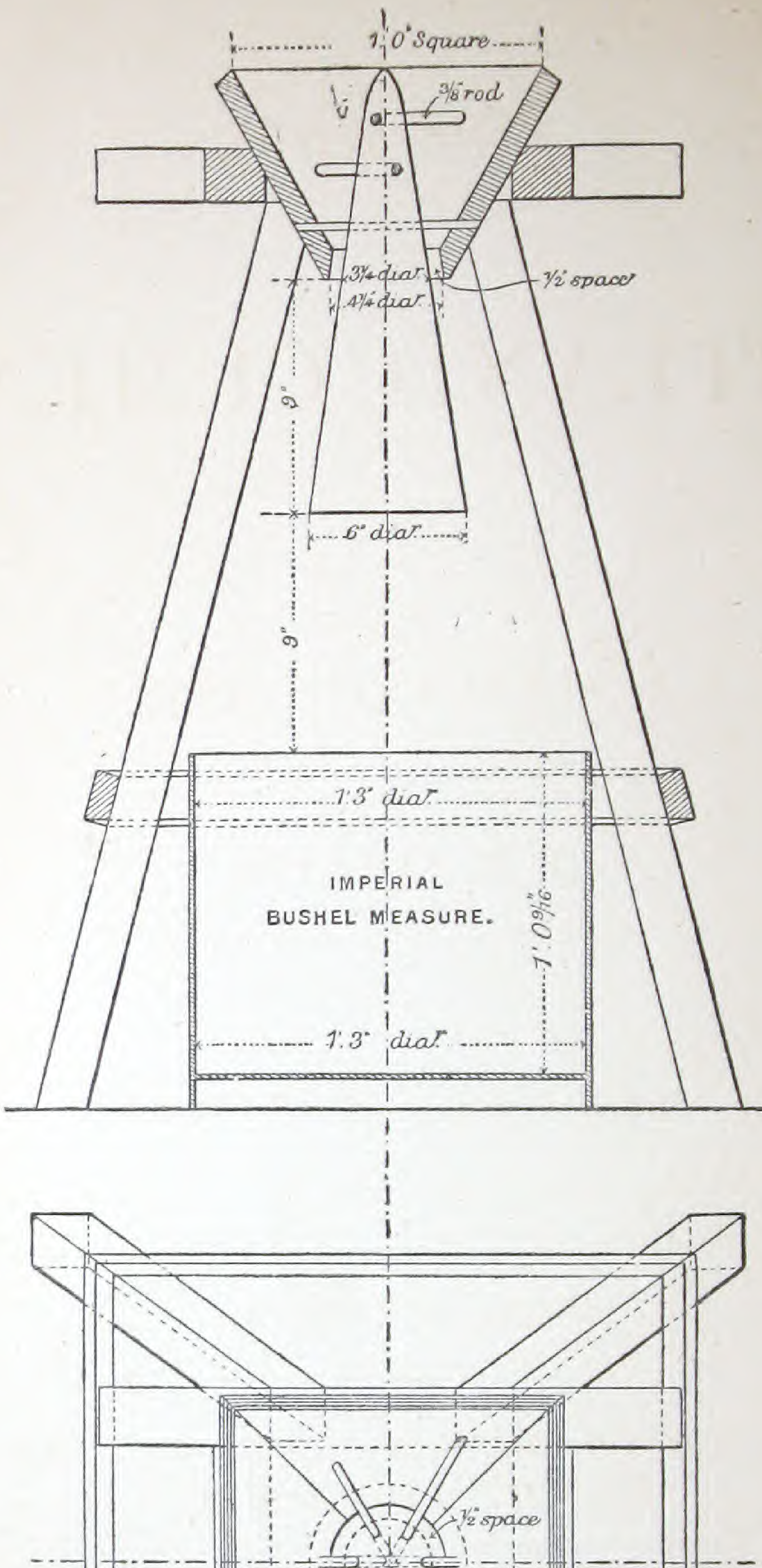
(SECOND EDITION.)

*WITH APPENDIX*

ON

THE RELATION OF CHEMICAL ANALYSIS TO QUALITY IN PORTLAND CEMENT.

E. & F. N. SPON, 125, STRAND, LONDON.
NEW YORK: 12, CORTLANDT STREET.
1888.



1' 0" Square
3/8 rod
3¼ diaʳ
4¼ diaʳ
½" space
9"
6" diaʳ
9"
1' 3" diaʳ
IMPERIAL
BUSHEL MEASURE.
1' 0 9/16"
1' 3" diaʳ
½" space
SCALE.
INCHES 12 9 6 3 0 1 FOOT

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A FEW WORDS ON

# PORTLAND CEMENT.

ALTHOUGH Portland Cement has during recent years received much attention from engineers, the writer is not aware that any manufacturer has published the result of that experience which can only be obtained by the constant and practical attention necessary to the production of thoroughly good quality; and he therefore trusts that the following remarks as to the usual tests and the manner of their application may not only be of general interest, but limit to some extent the anxiety of both manufacturers and engineers.

One special reason that leads him to do this is the conviction that whilst it is now being generally acknowledged that a cement giving a high **tensile strength** at short dates is not likely to prove one of a sound and progressive nature, engineers are not perhaps aware that by adding a "time in breaking" to the condition of tests, they have really raised the standard of 750 lbs. on the $1\frac{1}{2} \times 1\frac{1}{2}$ inch section equal to over 1,100 lbs. It is quite possible for an expert constantly gauging with fixed conditions as to temperature and atmosphere to get this result with a *safe* cement, but if the cement is to be tested by anyone with less experience, it is necessary for the manufacturer to work to a still higher standard, *i.e.*, to increase the proportion of lime to the highest possible point.

Tensile strength.

Some authorities think the danger of doing this can be counteracted by heavy burning. This is certainly not invariably the case. For instance, he has seen briquettes made from a cement weighing 123 lbs. to the bushel, testing at 7 days 1,200–1,300 lbs. on the $1\frac{1}{2} \times 1\frac{1}{2}$ inch section (and which at 2 years could not be broken with a strain of 1,430 lbs.), break a few months later at under 800 lbs. This was doubtless entirely due to the excess of lime which it was necessary to use in the original mixture, and he believes it is this high proportion which has been the real cause of recent concrete work failures; failures that were almost unknown before high tests came into vogue.

Breaking strain.

He would therefore suggest that a **breaking strain** to be made under ordinary conditions of 700 lbs. on $1\frac{1}{2} \times 1\frac{1}{2}$ inch section or (if with a time test of one minute) of 600 lbs., will give safer and ultimately better work than any higher requirement.

Tensile strain is one of the conditions of a specification most stringently enforced. At the same time it should be remembered that it is a test which depends greatly on the state of the atmosphere, and still more so on the skill of the manipulator. (See note, p. 10.)

With regard to the latter point it is by no means an infrequent occurrence to find two men making briquettes from the identical cement producing results varying from 25% to 33%.

It is therefore specially important that tests should be made by skilled labour and under fixed conditions of temperature, proportion of water, &c.; and the writer has added at the end some rules, which if adhered to will be found to assist in obtaining accurate results.

Weight per bushel.

**Weight per bushel** is only of much importance when taken in conjunction with fineness of grinding, but to get accurate comparative results, the cement should be fed through a standard hopper into a bushel measure, also of standard size, placed 18 inches below its mouth. (See Frontispiece. Drawing of Hopper and Bushel measure for ascertaining weight of Portland Cement as used in connection with Sir John Coode's specification.)

Fine grinding, however, makes considerable alteration in the weight test, as the following table will show.

An imperial bushel of best cement freshly ground passing through an

| | | Per Cent. | | lbs. |
|---|---|---|---|---|
| 80 Mesh Sieve | and leaving | 10 | residue, weighs | 110 |
| " | " | 20 | " | 116 |
| " | " | 25 | " | 121 |
| " | " | 35 | " | 123 |

When weight per bushel is specified it can only be ascertained by weighing a *whole* bushel; to weigh a given part and then multiply will not give a correct result.

All cement increases in bulk with age, therefore the weight per bushel becomes proportionately lighter.

For this reason, there will often be a discrepancy after a long voyage of several pounds between the weight per bushel on arrival and that ascertained at the time of shipment. (See page 11.)

**Fineness of Grinding** has been proved by Mr. John Grant and other authorities to be a most important factor in the strength of concrete, and should therefore have special attention. Fineness of grinding.

The extra cost of production to some extent counteracts the higher quality obtained, but the following degrees of fineness should be at least required.

| | | Per Cent. | | | Mesh Sieve. |
|---|---|---|---|---|---|
| For ordinary purposes | to leave under | 15 | residue, | through | 2500 |
| For general engineering | " | 10 | " | " | 2500 |
| For special work | " | 10 | " | " | 5800 |

Water test.

**Water Test** is one of the safest guards as to the soundness of cement.

Thin cakes or pats should be made up and placed upon pieces of glass or other non-absorbent material, and then, when thoroughly set, one cake should be immersed in water, the other being kept in the air. Care should be taken that the cement is thoroughly set before immersion, and for a slow-setting quality the pats may sometimes require 24 hours to become so. If after this the pats show cracks on the outer edge, the cement should not be passed unless it can be proved that the defect is due only to freshness of grinding, and can therefore be thoroughly remedied by air slacking.

A further useful test is to fill a test tube with gauged cement. Good cement always expands slightly, so that in course of 2 or 3 days the tube will crack; if, however, the expansion is so great as to blow the glass to pieces the cement should be regarded with great suspicion.

Chemical analysis.

**Chemical Analysis** * has no exact relation to the strength of cement, but is chiefly useful as detecting any excess of Sulphur or Magnesia, which are both regarded as dangerous elements if present in any large per-centage.

The following gives the average composition of a sound cement.

| | |
|---|---|
| Lime . . . . . | 59·20 |
| Silica . . . . . | 21·70 |
| Alumina . . . . . | 9·82 |
| Oxide of Iron . . . . | 3·78 |
| Sulphuric acid . . . . | 1·57 |
| Alkalies . . . . . | 0·50 |
| Magnesia . . . . . | 0·64 |
| Moisture . . . . . | 2·79 |
| | 100·00 |

* See also Appendix, p. 15.

**Specific Gravity** is useful in detecting the admixture of slacked lime or iron slag meal, as when so treated the cement will not give the 3·100 sp. weight, which is the standard of a freshly-ground genuine Portland.

**Slag Cement** has been for some time manufactured in Germany, and works have also been recently started in this country for its production. Slag cement.

Being a mechanical mixture of Iron Slag with Slacked Lime it is very different in its constitution from Portland Cement, which is a true chemical combination.

It is stated by its inventors to be fully equal in quality to Portland Cement; this is, however, not admitted by the highest authorities. It is distinguished by its light specific gravity, and by its colour; which is of a mauve tint, in powder, whilst the inside of the water pat when broken is deep indigo.

Its presence when mixed with Portland may be detected as follows, viz.: To a gill of water is added about a drachm and a half (80 drops) of sulphuric acid. Into this 25 grains of the cement is dropped and quickly stirred, so as to prevent any setting; and then immediately and whilst still stirring, Condy's fluid is allowed to fall in drop by drop until the red colour remains permanent.

A good genuine cement will require only 10 to 15 drops of the fluid (certainly not more than 20), whilst an adulterated cement will take considerably more (say 30 to 60), and a cement made from slag only probably over 200 drops.

Mr. H. B. Yardley, analytical chemist, has also formulated the following as a simple test for the same purpose, viz.: to place upon a clean silver coin a thin layer of the suspected cement, dropping thereon a small quantity of dilute sulphuric acid (1 acid to 7 water), and afterwards rinsing with water. If the cement is genuine, the thus treating with the acid will only slightly affect the colour of the silver; but if slag is present in any notable proportion, a dark brown stain will be produced upon the coin.

In conclusion, he would remind engineers of the great difficulty there is (especially during hot weather) of properly cooling the cement at the factory, and that it is therefore most desirable that, whenever the nature of the work will allow, **air slacking** for 3 or 4 weeks should be made a condition of the specification.

Air slacking.

The writer offers the foregoing as the result of many years' careful experience: an experience which leads to the conclusion that there is still very much to be learnt as to the laws which govern Portland Cement, more especially as they affect "time of setting" and "breaking strain."

SPECIFICATION SUGGESTION.

| | Weight per Bushel. | Tensile Strain per Square Inch. | | Fineness of Grinding. |
|---|---|---|---|---|
| | | 7 Days. | 28 Days. | |
| | lbs. | lbs. | lbs. | |
| Engineering work | 112 | 350 | 450 | Under 10 per cent. residue, through 2500 Mesh Sieve. |
| Special work . | 110 | 350 | 450 | Under 10 per cent. residue, through 5800 Mesh Sieve. |
| or for Sand Test 1 part of cement and 3 of standard (Leighton Buzzard) Sand. | | | | |
| Special work . | 110 | 100 | 170 | Under 10 per cent. residue, through 5800 Mesh Sieve. |

COMPARATIVE TESTS AT 7 DAYS' AGE OF THE SAME CEMENT EX WANDSWORTH, JULY 1886.

| A. Southam, Esq. | Hy. Faija, Esq. | Gordon & Co. | Eastwood, Kent Road. | Eastwood, Grays. | Gibbs, Grays. |
|---|---|---|---|---|---|
| lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 290 | *389 | 466 | †372 | †510 | 525 |

* Broken at the rate of 100 lbs. per 15 seconds.

† Made up by the same gauger.

EXAMPLE OF LOSS OF WEIGHT WITH AGE.

An imperial bushel of cement which weighed when

| | | |
|---|---|---|
| One day old . . . | 117 lbs., | reweighed |
| One month later . | 113 ,, | ,, |
| Two months later . | 108 ,, | ,, |
| Twelve months later | 103 ,, | |

## DIRECTIONS FOR TESTING THE TENSILE STRENGTH OF PORTLAND CEMENT.

**First.** In sampling a freight, several sacks or casks should be shot in a heap and well turned over together, the briquettes being made from this mixture. If samples are only taken from the mouth of the sacks or top of the casks, there is danger of the cement having become dead, and therefore not fairly representing the bulk. First.

**Second.** Spread out the sample for a few hours before gauging, so that it may become thoroughly cool and air slacked. **This is especially important in hot weather.** Second.

**Third.** Always weigh both cement, sand, and water before gauging, as a very slight excess of the necessary amount of sand or water will materially affect the result. See Grant on Cement, page 157, where Mr. Parkes says : Third.

"There would sometimes be a difference of 100 per cent., or 150 per cent., without any apparent cause, in the breaking strain of two bricks made from the same sample ; consistent results could only be obtained by adopting exact proportions of cement and water. In one experiment, he used four-tenths of a pint of water for each test block, when the breaking weight in four cases was 970 lbs., 980 lbs., 1,000 lbs., and 980 lbs. After that he made up two more samples, mixed with a half-pint of water instead of four-tenths of a pint, and these broke with 590 lbs., and 370 lbs. ;

two others made up with nine-twentieths of a pint broke with 750 lbs. and 375 lbs." Unfortunately every sample will require a varying amount according to the nature of its setting (quick or slow), fineness of grinding, and the state of the atmosphere, but as a rule from 18 to 20 per cent. will be sufficient, where 1-inch moulds are used.

Fourth. **Fourth.** Carefully clean the moulds with a slightly greasy cloth, and place them on iron plates.

Fifth. **Fifth.** Do not attempt to gauge too much cement at a time. If using 1-in. moulds, weigh $6\frac{1}{2}$ oz. cement and $1\frac{1}{4}$ oz. water to fill one mould, or 20 oz. cement and 4 oz. water enough to fill three moulds; if for $1\frac{1}{2}$-in. mould, weigh 40 oz. cement and $8\frac{1}{2}$ oz. water. Add the water little by little, working with a trowel until the mixture becomes a short harsh paste, discontinue adding water, but continue working with the trowel for a few minutes, when the paste will become fat and smooth. If only the proper quantity of water has been added, the sample will be stiff enough to stand with a straight edge, but if too much it will almost flow. In filling the moulds, considerable care is required to get rid of the air in the cement and make the briquette solid. The whole operation of gauging and filling the moulds should not occupy more than 4 to 5 minutes, and the quicker it is done, provided it is done properly, the better will be the result, for it is most important that the cement should be at rest before the setting action commences. The best form of moulds are those which screw together, and when these are used the briquettes should not be taken out until 24 hours after gauging. This "taking out" requires great care to avoid flaws, especially when "press" or spring moulds are used.

Atmospheric influence. **Atmospheric influence.** Heat and cold have both an important effect on the tensile strength of cement; therefore, care should be taken that during summer **the atmosphere of the testing-room is not so dry as to cause undue evaporation** of the proper proportion of the water added in mixing the test bricks, and that in winter the temperature does not fall so low as to cause this proportion of water to freeze before a thorough combination takes place.

**Temperature of Water.** It is also necessary for obtaining correct results that the temperature of the water used for gauging should be as nearly as possible the same during all seasons of the year, viz.: about 60° Fahrenheit. Temperature of water.

## Concrete Mixing.

**Good Concrete** can be made from clean gravel, river ballast, stone chippings, burnt clay, shingle, broken bricks, crushed flints, etc., etc.; and the proportion generally adopted by engineers is 1 of cement to 8 of these or similar materials, technically termed the aggregate. Good concrete.

To ensure satisfactory results, the following precautions should be taken :—

1. To have the cement shot into a dry shed a few days before using, so that it may be thoroughly cool and air-slacked.
2. To use *clean* water only.
3. The cement and aggregate should be raked or turned over together twice dry, and this operation again repeated whilst the water necessary for hydration is being added. This should always be poured through a rose (an ordinary watering-pot is as good a means as any), as throwing on from buckets washes the cement away from the aggregate. Repeat the mixing once more, and

the concrete is ready, *i.e.*, it has been turned over four times—twice dry, once whilst being watered, and once afterwards.

4. When the aggregate consists of crushed bricks or other porous material, it should be thoroughly wetted, and time allowed for absorption previous to use, otherwise it will take away part of the water necessary to affect the setting of the cement.
5. It is often desirable to add a proportion of sand to the aggregate to assist to fill up the corners. When this is done, care should be taken that the sand is sharp and clean—the coarser the better.
6. Concrete should be used at once after mixing, as to remix or disturb when partially set destroys its setting property.
7. When used for plastering over brickwork, this should be first well wetted.
8. Slow-setting cement gives, eventually, the strongest concrete.

The proportion of 8 and 1 is named as that usually specified; but with good tested cement a larger proportion of aggregate may be added.

These hints will be found useful in preventing the misuse of cement, but the writer would recommend all who are interested to know what cement can do for engineering works to read "Grant on the Strength of Cement;" or, for more general purposes, "Portland Cement for Users," H. Faija, C.E., and "Concrete: Its Use in Building," by Thos. Potter.

# APPENDIX.

## Six Years' Experience of Chemical Analysis in Relation to Quality in the Manufacture of Portland Cement.

Chemical analysis demonstrates whether a cement contains only its due percentage of lime, and also by the percentage remaining of carbonic acid whether this lime has been properly combined, during the process of burning with the silica and alumina.

This is most important to engineers and contractors, as the true cause of failure in concrete work may, in nearly all cases, be traced either to the use of an *excessive proportion of lime* in the original mixture or to some of the lime being present after burning in the "*free*," *i.e. not chemically combined, state.* This is indicated at once by the percentage of carbonic acid, which should in no case exceed 1·50 per cent.

In publishing the following yearly averages of the composition of cement, viz.:

| | 1882. | 1883. | 1884. | 1885. | 1886. | 1887. |
|---|---|---|---|---|---|---|
| Carbonic Anhydride. | 0·39 | 0·71 | 0·60 | 1·14 | 1·04 | 1·60 |
| Sulphuric " | 1·67 | 1·07 | 1·40 | 1·41 | 1·45 | 1·63 |
| Insoluble Silica . | 1·77 | 3·53 | 1·06 | 1·88 | 1·37 | 1·17 |
| Soluble " . | 20·90 | 19·31 | 22·52 | 23·24 | 22·79 | 21·63 |
| Alumina and Ferric Oxide . . . . | 12·08 | 13·37 | 9·60 | 10·82 | 11·34 | 10·87 |
| Lime . . . . . | 61·31 | 59·09 | 61·16 | 59·68 | 59·17 | 59·47 |
| *Alkalies, Water, &c. | 1·26 | 2·93 | 3·63 | 1·33 | 1·97 | 2·21 |
| | 99·98 | 99·80 | 99·97 | 99·50 | 99·04 | 100·00 |

* A separate determination of magnesia was not made until the years 1886 and 1887, when the highest percentage present was found to be 0·79 and the lowest 0·46, giving a mean of 0·62.

the Manufacturers need only add that it is with cement of this quality that the following important works have been supplied, *without one single case of failure*:—

| | |
|---|---|
| East London Harbour (under Sir J. Coode) . . . . . . | 3,000 tons. |
| Metropolitan Board of Works (under John Grant, Esq.) . | 6,000 tons. |
| Liverpool Docks (under G. F. Lyster, Esq.) . . . . . | 30,000 tons. |
| Newhaven Harbour (under F. Banister, Esq.) . . . . . | 10,000 tons. |
| Quebec and Esquimault Docks (under Messrs. Kinipple & Morris) . . . . . | 3,000 tons. |
| The Tay Bridge (under Messrs. Barlow & Son) . . . . | 10,000 tons. |
| Barrow Docks (under F. C. Stileman, Esq.) . . . . . | 7,000 tons. |
| Dublin Port and Harbour Board (under B. B. Stoney, Esq.) . . . . . | 3,000 tons. |
| Dublin Corporation Works (under Parke Neville, Esq.) . | 1,000 tons. |
| Cork Harbour Board (under P. Barry, Esq.) . . . . . | 2,500 tons. |
| Alexandra Docks, Hull (under Jas. Abernethy, Esq.) . . | 4,000 tons. |
| Victoria Dock, London (under Sir A. M. Rendel) . . . | 4,000 tons. |
| E. & W. India Dock, Tilbury (under Messrs. Manning & Baynes) . . . . . | 3,000 tons. |

AVERAGE TENSILE STRENGTH OF GIBBS & CO.'S PORTLAND CEMENT, ON $1\frac{1}{2}$ IN. × $1\frac{1}{2}$ IN. SECTION.

*Representing the Breaking of 5,000 Briquettes.*

| | 1882. | | 1883. | | 1884. | | 1885. | | 1886. | | 1887. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 days. | 28 days. | 7 days. | 28 days. | 7 days. | 28 days. | 7 days. | 28 days. | 7 days. | 28 days. | 7 days. | 28 days. |
| 1st January . | 1020 | 1325 | 930 | 1110 | 1012 | 1230 | 940 | 1275 | 950 | 1270 | 955 | 1110 |
| 15th " . | 995 | 1275 | 900 | 1130 | 980 | 1140 | 945 | 1180 | 965 | 1215 | 1015 | 1200 |
| 1st February . | 990 | 1235 | 1000 | 1290 | 1030 | 1230 | 1015 | 1325 | 1035 | 1310 | 1035 | 1310 |
| 15th " . | 915 | 1155 | 1045 | 1345 | 885 | 1100 | 1000 | 1130 | 1060 | 1260 | 1040 | 1235 |
| 1st March . . | 980 | 1235 | 1060 | 1320 | 1025 | 1270 | 1017 | 1300 | 935 | 1290 | 910 | 1120 |
| 15th " . . | 1055 | 1350 | 985 | 1320 | 1020 | 1280 | 1045 | 1160 | 930 | 1165 | 1020 | 1140 |
| 1st April . . | 1050 | 1185 | 970 | 1070 | 900 | 1225 | 957 | 1250 | 1060 | 1195 | 1135 | 1300 |
| 15th " . . | 1000 | 1230 | 1130 | 1260 | 957 | 1195 | 940 | 1220 | 1035 | 1225 | 980 | 1210 |
| 1st May . . | 965 | 1275 | 1025 | 1205 | 937 | 1200 | 1160 | 1380 | 975 | 1215 | 985 | 1205 |
| 15th " . . | 1002 | 1280 | 950 | 1255 | 950 | 1230 | 1072 | 1320 | 975 | 1270 | 1035 | 1335 |
| 1st June . . | 1010 | 1255 | 1020 | 1120 | 1050 | 1130 | 1170 | 1400 | 1050 | 1210 | 990 | 1295 |
| 15th " . . | 947 | 1200 | 995 | 1245 | 960 | 1210 | 1175 | 1320 | 985 | 1190 | 985 | 1200 |
| 1st July . . | 975 | 1080 | 900 | 1140 | 950 | 1150 | 945 | 1210 | 1000 | 1145 | 970 | 1200 |
| 15th " . . | 960 | 1270 | 945 | 1140 | 967 | 1170 | 1092 | 1310 | 997 | 1335 | 850 | 1120 |
| 1st August . | 937 | 1235 | 1040 | 1190 | 880 | 1030 | 1027 | 1380 | 1060 | 1430 | 970 | 1215 |
| 15th " . | 1065 | 1310 | 1100 | 1260 | 950 | 1070 | 935 | 1350 | 965 | 1215 | 1120 | 1305 |
| 1st September. | 970 | 1385 | 955 | 1090 | 965 | 1290 | 1050 | 1270 | 970 | 1190 | 895 | 1190 |
| 15th " . | 1005 | 1410 | 985 | 1180 | 965 | 1115 | 935 | 1225 | 1012 | 1200 | 875 | 1235 |
| 1st October . | 1140 | 1295 | 935 | 1110 | 975 | 1145 | 950 | 1220 | 1025 | 1300 | 1050 | 1290 |
| 15th " . | 1140 | 1265 | 925 | 1080 | 1040 | 1320 | 1065 | 1200 | 1020 | 1310 | 1037 | 1350 |
| 1st November . | 1080 | 1260 | 1100 | 1330 | 1185 | 1400 | 980 | 1210 | 1120 | 1360 | 1050 | 1280 |
| 15th " . | 970 | 1105 | 1000 | 1130 | 1080 | 1220 | 925 | 1105 | 965 | 1275 | 1100 | 1440 |
| 1st December . | 1050 | 1350 | 970 | 1290 | 1030 | 1325 | 1110 | 1335 | 1115 | 1370 | 1045 | 1310 |
| 15th " . | 965 | 1100 | 1185 | 1340 | 1035 | 1205 | 1060 | 1320 | 1025 | 1300 | 1070 | 1340 |
| Average | 1006 | 1252 | 1043 | 1206 | 988 | 1202 | 1021 | 1266 | 1009 | 1260 | 1005 | 1247 |

N.B.—These results were obtained by a skilled workman, whose sole occupation is to gauge cement, and were broken without any time condition.

With a time specification of 15 seconds per 100 lbs., or under ordinary circumstances of outside testing, the results would have probably been about 25 per cent. lower, viz. :—

7 days' average. 750 lbs.

28 days' average. 950 lbs.

The foregoing facts lead to the practical conclusion that the following are the only necessary characteristics for thoroughly sound cement:—

**Moderate tensile strain**: 350 lbs. per square inch at 7 days; 450 lbs. at 28 days, when broken without "time in breaking" conditions.

**Fineness in grinding**: The finer the better; for no engineering work should the residuum, after sifting through a sieve of 2,500 meshes to the square inch, exceed 10 per cent.

**Freedom from excess of lime** in chemical composition: This should not exceed 62 per cent. nor be less than 56 per cent.

**Minimum percentage** of magnesia not over **1** per cent., sulphuric acid not over 2 per cent., and carbonic acid not over 1·50 per cent.

**Good specific gravity**: 3·100 sp. weight.

**Pats,** when gauged up and put into water, after having become thoroughly set and hard, should not show any signs of cracks or undue expansion.

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